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# Nitrogen Requirements of Potatoes

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## ABSTRACT

**Nitrogen fertilizer applications, for maximum fertilizer efficiencies and crop yields, should be based on the N required by the crop during its various growth stages. The objectives of this paper were to identify the N requirements of the potato plant (*Solanum tuberosum* L.) during growth and to evaluate selected soil and plant tissue tests as indicators of the plant's N status. Growth analysis data and soil and petiole $NO_3$-N concentrations were obtained at predetermined time intervals from N fertilization treatments in replicated field studies on a coarse-silty mixed, mesic Durixerollic Calciorthrid soil. Maximum early tuber growth occurred when leaf area index was between 2.5 and 3.2 and the tops contained between 79 and 100 kg N ha$^{-1}$ at the start of linear tuber growth. A preplant N fertilizer application between 67 and 134 kg ha$^{-1}$ gave these characteristics under the experimental conditions. The maximum dry matter production rate per day (approx. 250 kg ha$^{-1}$) occurred when there was between 80 and 140 kg N ha$^{-1}$ in the plant tops and roots. An average tuber growth rate of 0.75 Mg ha$^{-1}$ day$^{-1}$ required a N uptake rate of 3.7 kg ha$^{-1}$ day$^{-1}$ to prevent the loss of N and dry matter from the tops and roots. Sufficient N was available for this rate when the soil $NO_3$-N concentration was $> 7.5$ mg kg$^{-1}$ (0.46-m soil depth), corresponding to 15 000 mg kg$^{-1}$ $NO_3$-N in the fourth petiole. Soil and petiole $NO_3$-N concentrations may be used to adjust the N fertilization rates during the growing season. This practice has the potential of increasing the overall N fertilizer use efficiency and final tuber yields within the climatic, disease, and variety limitations.**

***Additional index words:* *Solanum tuberosum* L., Uptake rate, Growth rate.**

NUTRIENT contents and assimilation by plants are the results of total plant growth rates and nutrient availabilities (2, 11, 18, 22). Relatively high preplant N applications can delay potato (*Solanum tuberosum* L.) tuber growth 7 to 10 days, particularly for indeterminate potato varieties (8, 14). Tuber dry matter production rates also vary with variety and season (9, 16, 17). Nitrogen has a major role in the production and maintenance of an optimum plant canopy for continued tuber growth through long growing seasons (13). During periods of high tuber growth rates, the demands for nutrients may exceed uptake rates and cause depletion of mobile nutrients from the tops to the tubers. If this depletion starts too early in the growing season, it may cause a premature canopy senescence (5, 6) and reduce final tuber yields.

Nutrient recommendations are available from research and extension publications in nearly all potato-growing areas (10, 15, 19, 20); however, none relate plant nutritional needs to growth and developmental stage. Widespread use of P and K fertilizers and nutrient release from native soil minerals ensure that many soils have adequate amounts of these nutrients available for crop production. Nitrogen fertilization is

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generally needed because of its mobility in soils and the large amounts needed by plants. A knowledge of the residual soil N, rate and amount of N mineralized from soil organic sources, and individual crop needs are all required to optimize N fertilizer recommendations. Recommendations based on these factors have the potential for improving N fertilizer efficiencies, as well as increasing production with indeterminate potato varieties. Both efficiency and production may be optimized by N fertilization practices that maximize plant and tuber growth rates early and during the growing season, while sustaining an adequate plant canopy.

Accumulation and distribution patterns of dry matter and nutrients in potato plants were previously separated into four growth stages (8). These four growth stages are as follows: I. *Vegetative*, plant development from planting until the start of tuberization; II. *Tuberization*, tubers forming on stolon tips but not appreciably enlarging; III. *Tuber growth*, tuber growth nearly linear if all growth conditions are optimum; IV. *Maturation*, vines start to yellow, leaf loss evident, and tuber growth rate slows, with most of the tuber dry weight increasing from the loss of materials from the tops and roots into the tubers.

The objectives of this study were to define the effect of N availability on potato plant growth characteristics and to develop techniques for making N fertilizer recommendations according to stage and rate of crop growth. Reported here is a summary of the N requirements of the potato plant at different growth stages and the relationships between selected soil and plant tissue tests and the plant's N status.

## METHODS AND MATERIALS

The data were obtained from three experimental field studies at Kimberly, ID from 1978 to 1980. 'Russet Burbank' potato seed pieces (0.06 kg) were planted 0.20 m deep and 0.23 m apart in 0.91 m wide rows between 19 and 25 April on a Portneuf silt loam soil (coarse-silty, mixed, mesic Durixerollic Calciorthid). This soil has a calcic layer beginning at about 0.4 m deep that restricts root penetration but not water movement. The potatoes followed cereal grains in the rotation to ensure a relatively low residual soil N content. Individual plots were six rows wide by 15 m long. A randomized block design was used with three or four replications.

All preplant fertilizers were broadcast and incorporated into the top 0.15 m of soil. Phosphorus, K, and micronutrient preplant applications were based on University of Idaho soil test recommendations (15). Preplant N was applied as $NH_4NO_3$, while the seasonal N applications were broadcast on the surface as urea immediately before an irrigation. Nitrogen rates and timing varied according to each experimental plan and were progressive (Table 1). Treatments with seasonal N rates and timing in 1979 and 1980 were designed to bracket the N needed to maintain tuber growth rates.

All experiments were sprinkler-irrigated with a 15- by 12-m sprinkler head spacing when the plant-available soil moisture dropped between 50 and 60% of the soil's field capacity. Soil moisture was monitored with tensiometers placed in the row at the seed-piece depth (0.20 m). Each irrigation brought the soil moisture back to near the field capacity. Metribuzin [4-amino-6-(1,1-dimethylethyl)-(methylthio)-1,2,4-triazine-5(4*H*)] herbicide and aldicarb [2-methyl-2(methylthio) propionaldehyde *0*-(methylcarbamoyl) oxime] insecticide were used in all experiments at 0.8 kg $ha^{-1}$ (a.i.) and 3.3 kg $ha^{-1}$ (a.i.), respectively.

Whole plant samples (a 1.5-m row segment) were taken from each plot on a 10- to 14-day interval from midtuberization (about 25 June) to vine kill (about 20 September). Plants from some treatments were selected for leaf area measurements and separated into leaves, stems, roots, and tubers. The "photosynthetic active" leaf area was measured with a Li-Cor Leaf Area Meter, model 3100. Active leaves were defined as those that showed no visible signs of senescence. The leaf area index (LAI) is defined as the ratio of the area of the leaf sample divided by the soil's surface area from which the sample was taken. Senescing leaves were also saved for total dry matter yield determination and chemical analysis. Leaves and stems were not separated on the remaining treatments. Fresh weights of tubers were recorded at each sampling after washing both the roots and tubers. All whole plant tissues were dried at 60 °C, weighed for dry matter determination, ground to pass a 40-mesh screen, and analyzed for total N, including $NO_3$-N (3). A composite sample of 30 to 40 petioles from the fourth leaf down from the growing tip was also taken from each plot at the same time as the whole plant samples. They were dried, ground, and analyzed for $NO_3$-N concentrations (12).

Soil samples (0 to 0.46 m) for $NO_3$-N analysis (12) and an incubation estimate of soil N mineralized from soil organic sources (4) were taken from each replication before any preplant fertilization. The N mineralized during the season was also estimated by a buried polyethylene bag tech-

**Table 1. Nitrogen treatments and the preplant soil analysis for N in each experiment.**

| Treatment | N applications ($N_f$) Total | Preplant | Seasonal | Preplant soil analysis Residual $NO_3^-$-N | Mineralizable N‡ |
|---|---|---|---|---|---|
| | kg $ha^{-1}$ | kg $ha^{-1}$ | month/day | mg $kg^{-1}$ | mg $kg^{-1}$ |
| | | | **1978** | | |
| 1† | 0 | 0 | 0 | | |
| 2† | 134 | 134 | 0 | 5 | 19 |
| 3† | 269 | 269 | 0 | | |
| 4 | 403 | 403 | 0 | | |
| 5† | 135 | 0 | (45)§ 21 June, 14 July, 2 August | | |
| 6 | 135 | 67 | (22) 21 June, 14 July, 2 August | | |
| | | | **1979** | | |
| 1† | 134 | 134 | 0 | | |
| 2† | 269 | 269 | 0 | 6 | 16 |
| 3 | 170 | 0 | (34) 11 June, 20 June, 10 July, 27 July, 16 August | | |
| 4† | 225 | 0 | (45) 11 June, 20 June, 10 July, 27 July, 15 August | | |
| 5 | 280 | 0 | (56) 11 June, 20 June, 10 July, 27 July, 15 August | | |
| 6† | 180 | 0 | (45) 20 June, 10 July, 27 July, 15 August | | |
| 7† | 203 | 67 | (34) 20 June, 10 July, 27 July, 15 August | | |
| 8 | 270 | 134 | (34) 20 June, 10 July, 27 July, 15 August | | |
| | | | **1980** | | |
| 1 | 235 | 235 | 0 | | |
| 2† | 309 | 84 | (45) 14 June, 4 July, 18 July, 30 July, 11 August | 4 | 17 |
| 3† | 342 | 162 | (45) 4 July, 18 July, 30 July, 11 August | | |
| 4 | 342 | 162 | (45) 4 July, 18 July, 30 July, 11 August, 18 August | | |
| 5 | 432 | 162 | (45) 27 June, 11 July, 18 July, 30 July, 5 August, 11 August | | |
| 6† | 342 | 162 | (45) 4 July, 18 July, 30 July, 11 August | | |
| 7† | 387 | 162 | (45) 4 July, 18 July, 30 July, 5 August, 11 August | | |
| 8† | 224 | 162 | (31) 20 June, 3 July | | |
| 9† | 450 | 162 | (72) 20 June, 3 July, 17 July, 31 July | | |

† LAI determined on these treatments.
‡ N mineralized at 30°C for 3 weeks (3).
§ Per treatment.

nique (21). Soil $NO_3$-N concentrations in the surface 0.46-m soil layer in each treatment were measured at each whole plant sampling in 0.02-m soil cores combined across replications. Data were analyzed by analysis of variance and Duncan's multiple range tests.

All remaining plant tops were removed from all plots on about 20 September in preparation for final harvest. Tubers were then mechanically harvested from two nonborder rows each 9 or 12-m long from the center of each plot during the first week of October. Tuber yields and the yields of graded tubers (1) were determined immediately after harvest. The specific gravity of tubers was determined on about 4 kg of USDA #1 tubers from their weights in air and water.

## RESULTS AND DISCUSSION

The final tuber yields were increased by N fertilization compared with the control treatment in 1978 (Table 2). There were generally no apparent yield differences between the preplant N and the seasonal or split N treatments, except in 1980. In 1980 tuber yields were significantly increased by split applications at a total N rate of 224 to 235 kg ha$^{-1}$ (treatment 1 vs. 8). Yields were further increased from additional seasonal N (treatments 5, 6, 7).

Nitrogen fertilization generally increased the percentage of USDA #1 tubers with a corresponding decrease in undersized tubers (data not shown). The higher percentages of larger tubers (>0.28 kg) in 1980 compared with 1978 and 1979 reflected continued late-season tuber growth (August and September). All tuber specific gravities were $\geq$1.076 Mg m$^{-3}$, indicating high-quality, mature tubers. The highest N fertilization rate during tuber growth did not significantly reduce specific gravities or percentage of USDA #1 tubers in 1979 (treatment 5 vs. 8), but did in 1980 (treatment 5 vs. 9) when a higher seasonal N fertilization rate was applied (72 vs. 56 kg ha$^{-1}$).

Most of the tuber yield differences (Table 2) can be explained by a delay in early tuber growth or insufficient N being available for optimum tuber growth during August and early September. Tuber yields were reduced at the first and second samplings by preplant N fertilization rates $\geq$ 134 kg ha$^{-1}$ (Fig. 1). The tuber yields for 134 kg N ha$^{-1}$ were similar to the lower preplant N fertilization treatments by about 10 July. Higher preplant N fertilization rates further delayed tuber growth at even later samplings. Maximum early tuber growth occurred when $\leq$ 67 kg ha$^{-1}$ N was applied preplant; however, the tuber growth rate decreased thereafter because of insufficient early top growth or leaf area (Table 3), or the lack of additional N applications. The tuber growth rate in the 134 kg ha$^{-1}$ preplant N treatments also slowed by 5 August without any additional N fertilization during the growing season (Fig. 1). The 269 kg ha$^{-1}$ preplant N treatment achieved similar final tuber yields (Table 2) as the lower preplant N fertilization rates because its relative tuber growth rate was 1.1 to 2.2 times greater than the other N treatments in late season (data not shown). Much of this additional tuber growth came from more dry matter being translocated from the tops into the tubers during this time interval and a slightly higher LAI (Table 3).

These tuber growth data suggest that between 67 and 134 kg ha$^{-1}$ was the optimum preplant N fertilization

**Table 2. Effect of N treatment on final tuber yields, size distribution, and specific gravity.**

| N Treatment† | Total final tuber yields‡ | USDA tuber grades‡ | | | Tuber specific gravity‡ |
|---|---|---|---|---|---|
| | | #1s | #2s | >0.28 kg | |
| | Mg ha$^{-1}$ | % | | | Mg m$^{-3}$ |
| | | **1978** | | | |
| 1 | 32.6 a | 52.2 a | 6.6 a | 7.0 a | 1.087 c |
| 2 | 45.0 b | 66.5 b | 3.1 a | 4.2 a | 1.086 bc |
| 3 | 48.6 bcd | 67.9 b | 5.3 a | 8.7 a | 1.085 bc |
| 4 | 49.6 cd | 69.5 b | 5.9 a | 10.6 a | 1.082 a |
| 5 | 46.8 bc | 71.0 b | 7.0 a | 10.4 a | 1.082 a |
| 6 | 47.5 bcd | 68.7 b | 5.5 a | 7.6 a | 1.083 ab |
| $S_{\bar{x}}$§ | 7.7 | 7.5 | 0.9 | 3.5 | 0.108 |
| | | **1979** | | | |
| 1 | 46.6 a | 69.2 a | 11.4 a | 11.5 a | 1.081 a |
| 2 | 43.9 a | 79.3 a | 5.4 a | 10.7 a | 1.082 a |
| 3 | 47.3 a | 72.0 a | 10.9 a | 11.4 a | 1.080 a |
| 4 | 44.5 a | 71.0 a | 12.0 a | 11.2 a | 1.081 a |
| 5 | 42.9 a | 73.6 a | 8.4 a | 8.1 a | 1.082 a |
| 6 | 44.4 a | 67.4 a | 14.9 a | 10.4 a | 1.081 a |
| 7 | 44.6 a | 71.6 a | 11.0 a | 11.0 a | 1.081 a |
| 8 | 46.2 a | 71.7 a | 12.3 a | 12.3 a | 1.080 a |
| $S_{\bar{x}}$ | 4.1 | 6.9 | 5.6 | 1.9 | 0.125 |
| | | **1980** | | | |
| 1 | 46.6 a | 75.7 c | 18.0 a | 52.2 a | 1.080 bc |
| 2 | 50.2 b | 65.4 b | 28.1 c | 52.0 a | 1.079 b |
| 3 | 52.0 bc | 80.6 c | 13.4 a | 55.6 a | 1.078 ab |
| 4 | 49.7 ab | 74.1 c | 19.6 ab | 56.5 a | 1.079 b |
| 5 | 55.1 cd | 78.2 c | 15.6 a | 54.3 a | 1.078 ab |
| 6 | 55.9 d | 75.8 c | 18.8 ab | 56.9 a | 1.078 ab |
| 7 | 54.8 cd | 75.9 c | 17.6 ab | 55.1 a | 1.079 b |
| 8 | 51.0 b | 65.7 b | 25.0 bc | 50.3 a | 1.082 c |
| 9 | 51.7 bc | 51.7 a | 38.0 d | 44.9 a | 1.076 a |
| $S_{\bar{x}}$ | 4.7 | 6.9 | 1.2 | 5.8 | 0.096 |

† See Table 1 for treatment descriptions.
‡ Treatment mean within a year and category followed by the same letter are not significantly different at the 5% probability level according to Duncan's multiple range test.
§ Standard error of means.

**Table 3. Effect of N fertilization treatment on leaf area index (LAI), 1978.**

| Treatment | Sampling date† | | | | | |
|---|---|---|---|---|---|---|
| | 20 June | 30 June | 10 July | 24 July | 5 August | 21 August |
| 1 | 0.84 a | 1.64 a | 2.18 a | 2.28 a | 2.68 a | 1.12 a |
| 2 | 0.92 a | 2.48 bc | 3.92 bc | 3.85 bc | 3.31 b | 2.34 b |
| 3 | 1.36 b | 2.90 c | 4.16 c | 4.50 c | 4.08 ab | 2.38 b |
| 5 | 0.90 a | 1.91 ab | 2.94 ab | 3.18 ab | 4.02 b | 2.22 b |
| $S_{\bar{x}}$‡ | 0.09 | 0.21 | 0.35 | 0.78 | 0.24 | 0.35 |

† Treatment means within a sampling date followed by the same letter are not significantly different at the 5% probability level according to Duncan's multiple range test.
‡ Standard error of means.

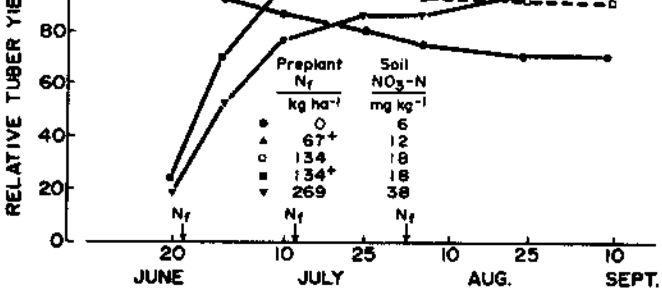


**Fig. 1. Effect of N fertilization treatment on relative tuber yields at each sampling date. Representative data shown from 1978 and 1979. (+) denotes additional seasonal N fertilizer applied; dashed line indicates a treatment without any seasonal applied N fertilizer; dates of seasonal N fertilization indicated by $N_f$.**

rate in these experiments. These rates, combined with the initial soil $NO_3$-N content, the N mineralized from soil organic matter, the N taken up by the plant, and other possible N losses, gave between 12 and 18 mg $kg^{-1}$ $NO_3$-N in the surface 0.46-m soil layer on 20 June (Fig. 1). The plants (excluding tubers) in these treatments contained between 78 and 100 kg N $ha^{-1}$ by the start of growth stage III (tuber growth) and had a LAI of between 2.5 and 3.2. The N content of the plant was linearly related to the LAI in all three experiments [LAI= (0.033 kg N $ha^{-1}$) − 0.1, $r$=0.86, $n$=85].

The N contents of the plants (tops plus roots) at the start of a sampling interval were curvilinearly related to the average dry matter production rates during that sampling interval (Fig. 2). Near maximum dry matter production rates occurred between about 80 and 140 kg N $ha^{-1}$ with the regression maximum at about 120 kg N $ha^{-1}$. The dry matter production rates tended to decrease at larger N contents, possibly because of increased respiration losses from larger plants. Plants with N contents > 120 kg $ha^{-1}$ generally had a LAI > 4 (data not shown).

Continued late season tuber growth requires tops with the capability to produce sufficient dry matter for both tuber and top growth and a N uptake rate sufficient for both of these needs. The average N uptake rate during a sampling interval was compared with the ratio of the change in whole-plant N content divided by the change in tuber N content during that same sampling interval (Fig. 3). A ratio > 1 indicates that the N uptake rate exceeded tuber growth needs; a ratio < 1 indicates that the N uptake rate was insufficient for tuber growth needs. Data from the first sampling interval are not shown because full tuber growth had not always started. These data (Fig. 3) indicate N uptake should be > 2.4 kg $ha^{-1}$ day $^{-1}$ to prevent N from being depleted from the tops and roots. This amount of N would be sufficient for a fresh tuber growth rate of 0.75 Mg $ha^{-1}$ day $^{-1}$ assuming 15.5 g N $kg^{-1}$ and 210 g $kg^{-1}$ dry matter in the tubers. The average fresh tuber growth rate during the growth stage III sampling intervals varied from 0.6 to 0.9 Mg $ha^{-1}$ day $^{-1}$ in the three experiments.

Continued high rates of dry matter production requires some new vegetative growth to offset leaf aging effects. To do this the N uptake rate should exceed that needed for tuber growth and should occur before needed because $NO_3$-N must be reduced and incorporated into the necessary compounds before growth can occur. A comparison of the average N uptake rate in a sampling interval with the plant's dry matter balance in the following interval showed that a N uptake rate of about 3.7 kg $ha^{-1}$ $day^{-1}$ was necessary to maintain the dry matter balance (Fig. 4). A similar comparison showed that a N uptake rate of 1.6 kg $ha^{-1}$ $day^{-1}$ was sufficient to maintain the plant's dry mattter balance in the same sampling interval (data not shown). However, this rate (i.e., 1.6) would have a N balance of < 1 (Fig. 3) and would eventually cause canopy senescence and reduce tuber yields if the senescence occurred too early in the growing season. A N uptake rate sufficient to maintain the N balance had a dry matter balance of about 0.83 in the next sampling interval (Fig. 3 vs. Fig. 4).

The N required by the tubers varied from 2 to 3 kg $ha^{-1}$ $day^{-1}$ in this study. In a previous study the maximum N uptake rate for tuber growth was 4 kg $ha^{-1}$ $day^{-1}$ for the same potato variety (8). These data suggest that the N management technique should provide enough available N to compensate for different tuber growth rates. Plant tissue and soil tests can be used to monitor the nutritional status of plants and to adjust fertilization rates, provided they are correlated with plant growth and yield responses.

The average N uptake rate was related to the average soil $NO_3$-N concentration within a sampling interval

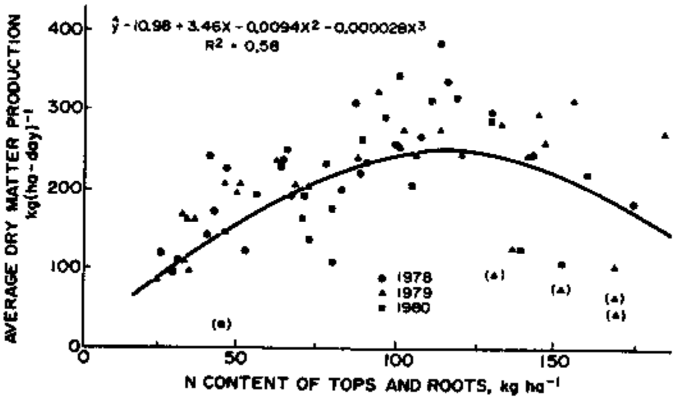


**Fig. 2. The relationship between the average dry matter production per sampling interval and the N content of the tops and roots at the start of the respective sampling interval. ( ) denotes points not included in the regression equation because of late season disease problems.**

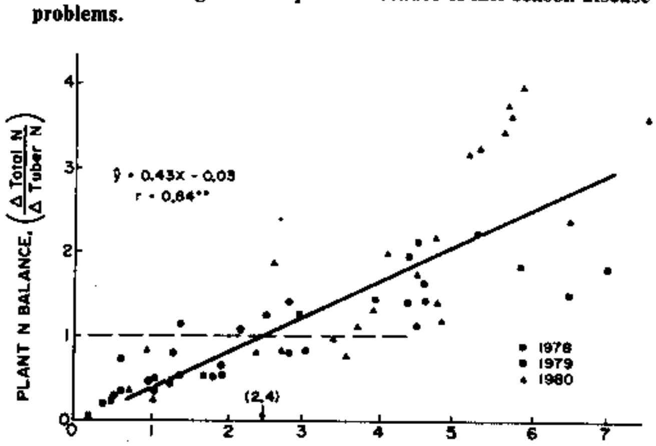


**Fig. 3. The relationship between the average N uptake rate and the N balance of the total plant and tubers for the same sampling interval during growth stage III.**

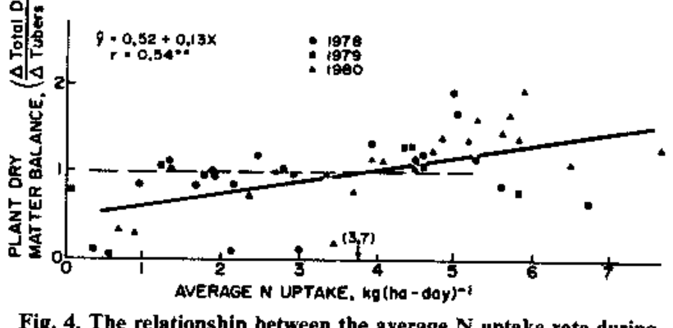


**Fig. 4. The relationship between the average N uptake rate during one sampling interval and the dry matter balance of the total plant and tubers for the next sampling interval during growth stage III.**

during growth stage III (Fig. 5). The N uptake rate increased rapidly up to about 7.5 mg $kg^{-1}$ soil $NO_3$-N with a slower increase at higher concentrations. Treatments with seasonal N fertilizer applications tended to have N uptake rates above the dashed line at the lower $NO_3$-N concentrations. A soil $NO_3$-N concentration of 7.5 mg $kg^{-1}$ was generally sufficient for a N uptake rate of 3.7 kg N $ha^{-1}$ $day^{-1}$. This relationship would be a function of temperatures, soil moisture, plant growth activities, and the soil N mineralization rate.

The soil $NO_3$-N concentrations were also related to the petiole $NO_3$-N concentrations (Fig. 6). Petiole $NO_3$-N concentrations were generally > 15 000 mg $kg^{-1}$ when the soil $NO_3$-N concentration was ≥ 7.5 mg $kg^{-1}$. Nitrogen fertilization practices that maintain petiole and soil $NO_3$-N concentrations of 15 000 and 7.5 mg $kg^{-1}$, respectively, should provide sufficient available N for an uptake rate of about 3.7 kg N $ha^{-1}$ $day^{-1}$ during growth stage III. Smaller amounts of N would be required when other environmental factors become limiting, i.e., temperature and solar radiation during growth stage IV.

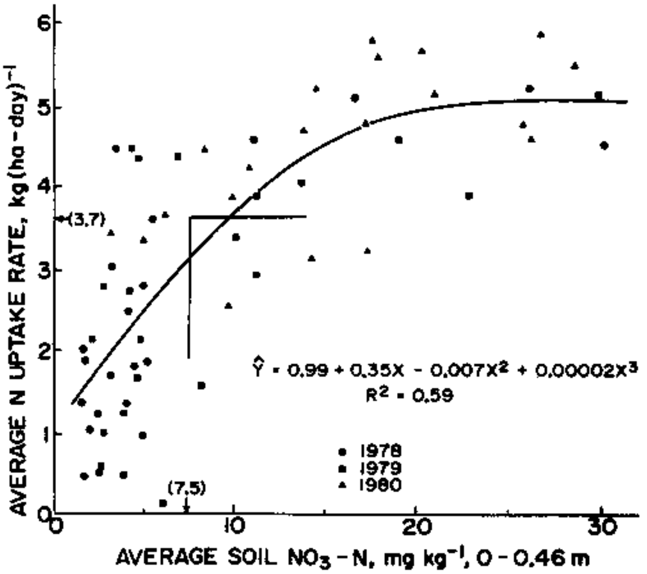


**Fig. 5. The relationship between the average soil $NO_3$-N concentration and the average N uptake rate within a sampling interval during growth stage III.**

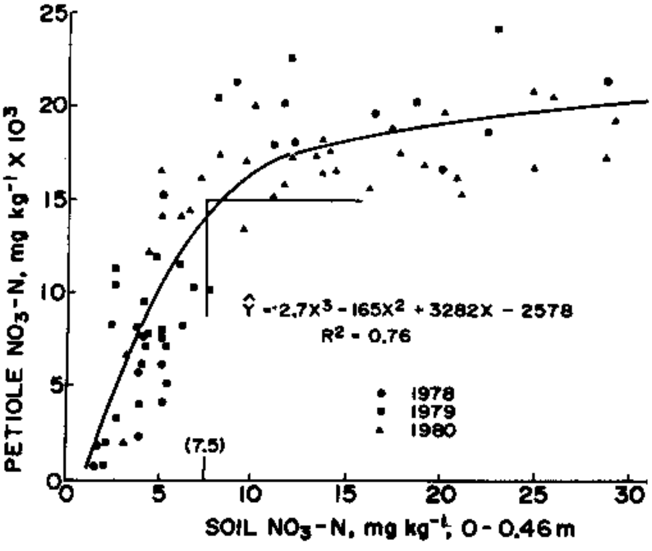


**Fig. 6. The relationship between soil and petiole $NO_3$-N concentrations.**

## SUMMARY

Maximum early potato tuber growth occurred when the plant contained between 78 and 100 kg N $ha^{-1}$ at the start of growth stage III, and when the LAI was between 2.5 and 3.2. At the same time, the $NO_3$-N concentrations in the 0- to 0.46-m root zone ranged from 12 to 18 mg $kg^{-1}$. An application of preplant N fertilizer between 67 and 137 kg N $ha^{-1}$ gave these characteristics under the experimental conditions. The optimum amount of fertilizer N would depend on the residual soil $NO_3$-N concentrations and the amount of N mineralized from soil organic sources between planting and the start of growth stage III. Maximum dry matter production rates occurred when there was between 80 and 140 kg N $ha^{-1}$ in the potato plant (without the tuber N content). A N uptake rate of 3.7 kg $ha^{-1}$ $day^{-1}$ was necessary to prevent the loss of N and dry matter from the tops and roots to the tubers during growth stage III. Sufficient N was available for this rate when the soil $NO_3$-N concentration was > 7.5 mg $kg^{-1}$, corresponding to 15 000 mg $kg^{-1}$ $NO_3$-N in the potato petiole.

The response of the potato plant to the available N supply is an important determinant for accurate N fertilizer recommendations. Development of recommendations according to dry matter production and N uptake rates during each crop growth stage has the potential of increasing the N fertilizer use efficiencies and may also increase the final tuber yield within the climatic, disease, and variety limitations. These techniques should promote early tuber growth and sustain the maximum tuber growth rates until scheduled harvest. A knowledge of the residual soil $NO_3$-N concentrations, the rate and amount of N mineralized from the soil organic N sources, and the actual N fertilizer efficiencies must also be known for this practice to be successful. Methods for estimating the N mineralization rate during the growing season are available (7, 21). Additional data on the N uptake, partitioning, and translocation of N fertilizer applied at the different potato plant growth stages will follow in a later paper.

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